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(54) IMPROVEMENTS IN ROTARY MACHINES

(71) I, FERDINAND JEANDEL, a French Citizen of 39 rue Poussin 75, Paris, XVI, France do hereby redeclare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed to be particularly described in and by the following statement:—

The present invention relates to rotary machines of the kind which can be used as a motor or as a compressor or as a motor-compressor, a machine of this kind having a rotor which rotates inside a stator, in which a fluid is successively compressed and decompressed in chambers of decreasing and increasing volume, each chamber being limited by the walls of at least one helicoidal groove in the surface of the rotor, by the surface of the stator and by the surface of at least one valve device with peripheral vanes which engage in the helicoidal groove, the valve device rotating in a longitudinal plane of symmetry of the rotor, the object of the invention being in particular to improve the performance of a machine of this kind, particularly its efficiency and the power delivered, so as to make the machine suitable for a wider variety of applications, compared to the known machines of this kind, and so as to reduce the weight of the machine and its cost of construction.

Machines of this kind are known in which a gas is compressed in a chamber decreasing volume limited by the surface of an internal stator in the form of a solid torus, by the walls of a helicoidal groove in the surface of a rotor, which completely encloses the internal stator except where the periphery of the stator is joined to an external housing, and by at least one rotary valve device which has projecting vanes which engage in the helicoidal groove. The known device, which is represented diagrammatically in figures 1, 2 and 3, consists essentially of a rotor 3 which rotates about an axis 3 in the direction of the arrow 9. The rotor 2 contains a helicoidal groove between ribs 8 in which engage with close clearances the vanes of two valve devices 4. Each valve device 4

is a wheel which rotates on an axis 5 which extends perpendicular to the axis 3 of the rotor in the longitudinal central plane of symmetry of the latter. The two valve devices 4, in the form of wheels with peripheral vane blades, rotate in a common vertical plane, between the two symmetrical halves of an internal stator 1 in the form of a solid torus. All these parts are contained in a stationary external housing 1'. The internal toroidal stator is attached to the outer housing 1' by an annular bridge which is in the transverse plane of symmetry of the internal stator 1. The vanes project radially outwards beyond the surface 6 of the stator. As already mentioned, the vanes engage in the helicoidal groove of the rotor. Figure 2 is a transverse section of the machine, taken along the line II-II in figure 1. Regarded from this direction the projection of the rib 8 assumes the form of a spiral. Figure 3 is 3-dimensional representation of the inside of one half of the rotor, showing a helicoidal rib 8.

Assuming that the rotor is rotating, as indicated by the arrow 9 in figure 1, the gas enters through an inlet port 10, entering a helicoidal chamber limited by the first rib 8 of the helicoidal groove in the surface of the rotor 2, by the surface 6 of the solid torus which forms the stator 1, by a vane of the upper wheel 4 and a vane of the lower wheel 4.

With rotation of the rotor, the stator vanes follow the helicoidal groove in the rotor, progressively reducing the volume of the helicoidal chamber, which is at least in the middle region of the device at 12. During this movement the gas in the helicoidal chamber is compressed. In the subsequent phase of the process the gas expands, on its way from the middle region 12 to the outlet port 11. In the case of an internal combustion engine, the combustible mixture entering the engine through the inlet port 10 is compressed, reaching maximal compression at the middle region 12, where it is ignited, subsequently expanding on its way from the

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middle region 12 to the outlet port 11, this being the working stroke of the engine. On the other hand, if the device is merely a compressor, the device is limited to the part between 10 and 12.

This known device is already approaching the efficiency and power of a conventional motor or compressor. It can be used in the form of an internal combustion engine or a Diesel cycle engine. It can be arranged as a multistage motor comprising several compression stages and several expansion stages, arranged in series or in parallel. Nevertheless the known device has several disadvantages.

In particular the power to weight ratio and the thermal efficiency are comparatively low, limiting the field of application. Furthermore the device tends to heat up locally, particularly in the region of the combustion chamber, if the device is in the form of an internal combustion engine with the combustion chamber incorporated in the rotor. The local overheating requires excessive clearances to be provided between the parts of the rotor and the parts of the stator.

The object of the present invention is to remove these disadvantages by modifying and rearranging the parts of the rotor and of the stator, at the same time taking steps to increase the power to weight ratio and the thermal efficiency of the device.

According to the invention there is provided a rotary machine which can be used as a motor, a compressor or a motor-compressor, comprising a first member in the form of a rotor which rotates inside a second member in the form of a stator, the machine being arranged in such a way that working fluid is compressed and subsequently expands in a succession of chambers of first decreasing and then increasing volume, limited by the walls of at least one helicoidal-spiral groove in the surface of one of the said members (that is, either the rotor or the stator), by the wall of the other of the said members (that is, either the stator or the rotor), and by at least one valve device whose peripheral vanes engage in the groove, the valve device rotating in a longitudinal plane of symmetry of one of the said rotor or stator members, characterised in that one of the said stator or rotor members has at least one projecting part in the form of a body or revolution, the other of said rotor or stator members, the surface of which is provided with the said helicoidal spiral groove, having at least one wall part obtained by a complete truncature of the ribs of the helicoidal-spiral groove in the region facing the said projecting part and having a shape complementary thereto, there being very little clearance between these parts, which are shaped and arranged in the machine so as to modify the flow of fluid through the machine in such a manner that

the fluid is subjected to an additional greater compression.

The invention will now be described on the basis of the several examples represented in the drawings, in which:

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Figures 1 and 2, which have been mentioned above, represent diagrammatically an internal combustion engine according to the invention.

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Figure 3 is a 3-dimensional view of one half of the rotor of the known device represented in Figures 1 and 2.

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Figure 4 is an axial section through one version of a machine according to the invention, in the form of an internal combustion engine.

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Figures 5 and 6 illustrate diagrammatically the path taken by the burnt gases from the combustion chamber into the helicoidal groove in the rotor of the machine of figure 4.

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Figure 7 is a diagrammatical representation of the machine of figure 4.

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Figure 8 represents diagrammatically a machine according to the invention arranged to function as a compressor.

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Figures 9, 10 and 11 represent another version of the machine of figure 4.

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Figures 12, 13, 14, 15, 16, 17, 18, 19, 20, 21 and 22 represent diagrammatically several other versions of the machine according to the invention.

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Figure 23 is a still further version of the machine according to the invention.

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Figure 24 is a detail of the volute surrounding the supercharger of the machine of figure 23.

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Figure 25 shows, drawn to a larger scale, a vane of a valve device in the machine of figure 23.

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Figure 26 shows in somewhat more detail two vanes of a valve device engaged in the helicoidal grooves, showing in cross section the rib between the grooves.

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Figure 27 is a section through the axis of the valve device in the machine of figure 23.

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Figures 28 to 33 show very diagrammatically several different ways of joining the two parts of the machine together.

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With reference to figure 4, this shows a preferred version of the rotary machine according to the invention, in the form of an internal combustion engine equipped with a centrifugal precompressor for the entering gas and a device for recovering the residual energy in the exhaust gases. The machine consists of a rotor 2 whose surface contains a helicoidal groove, the rotor rotating about an axis 3 in the direction of the arrow 9.

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The rotor shaft rotates in bearings 24, 25 in a stationary outer housing 1'. The rotor has outer parts 27, 28 which completely enclose an internal stator 1, except where the stator is joined by a peripheral bridge con-

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nction 29 to the outer housing 1'. The two outer parts 27, 28 contain between them symmetrically a hollow torus which has a peripheral gap on its transverse plane of symmetry, to give room for the bridge connection 29. The stator 1 is a body of revolution whose axis is the axis of the rotor 2. The concave inner surface of the rotor contains a helicoidal-spiral groove, the rib 8 being partly cut away, as will be described further below. The helicoidal-spiral groove in the two outer parts 27 and 28 is a precise continuation of the helicoidal groove in the central part of the rotor, so that the inner surface of the rotor, which faces the outer surface 6 of the stator 1, contains a continuous helicoidal groove for guiding the flowing gases. In the known device the internal stator 1 consists of two solid half-toruses containing between them the two toothed wheels 4, each of which is mounted to rotate on an axis 5. In the improved machine according to the present invention, on the other hand, the internal stator is in the form of a solid torus 25 which has a projecting part 14, in the form of a body of revolution, the part 14 being of one piece with the solid torus proper. The rotor 2 has an annular recess 32 corresponding to the annular projection 14 on the stator, so that only a very small clearance 18 remains between these two parts. The cross section of the annular projection 14 is such that it completely covers at least one tooth or vane of each wheel 4, as shown in Figures 4 and 7. Consequently, the rib 8 of the rotor is entirely removed in the region of the projection 14, and is partly removed on either side of this region. The helicoidal groove is subdivided by the vanes into a number of chambers a, b, c, d, e, f, of successively decreasing volume, and a number of chambers g, h, i, j, k, l, m, n, o, p, q, r, of successively increasing volume.

The other end of the rotor 2, that is to say the end of the rotor which has the outer part 27, contains a central chamber 16, which itself contains a combustion chamber 17, a certain amount of clearance remaining between the combustion chamber 17 and the wall of the chamber 16. The combustion chamber 17 is fixed to the outer housing 1' of the machine. The outer housing 1' also contains a centrifugal impeller 13 and a centripetal turbine rotor 22. The impeller 13 is fixed to the outer part 27 of the rotor 2, rotating with the latter about the axis 3, inside the outer housing 1'. The centripetal turbine rotor 22 is situated on the opposite side of the machine, compared to the centrifugal impeller 13, that is to say on the opposite side of the transverse plane of the stator 1 and rotor 2. The centripetal turbine rotor 22 is fixed to the outer part 28 of the rotor 2.

When the engine is in operation, the fluid, that is, air or combustible mixture, enters the engine through an inlet port 33 in the outer housing 1', as shown by the arrow. The fluid is aspirated by the centrifugal impeller 13, which applies a precompression. Leaving the impeller 13 the air or combustible mixture passes through a diffuser 13', just downstream of the impeller through passage 30 in the outer housing 1', and through a peripheral bridge connection 29 into the helicoidal groove of the rotor. In the helicoidal groove the fluid is trapped by the vanes in chambers a, b . . . f, in which it is progressively compressed. From the chambers e and f the compressed fluid escapes through branch channels 15 and so enters the central chamber 16 which contains the combustion chamber 17. Little or no fluid can escape through the very narrow clearance 18 between the parts 14 and 32. The compressed fluid entering the chamber 16 forms a layer of moving gas around the combustion chamber 17. After entering the chamber 16 the fluid penetrates inwards through a series of openings 19, 20 into the interior of the combustion chamber 17. The combustion chamber is secured to a connecting stud 21 fixed to the outer housing 1'. In a modification the combustion chamber is fixed to the rotor 2. The connecting stud 21 may contain one or more fuel injection nozzles 34.

If desired the amount of clearance 18 between the projection of the stator and the surface of the recess 32 in the rotor can be great enough to allow a certain amount of air to pass through, to act secondary air, in order to limit the temperature of the impinging flame downstream of the combustion chamber 17.

The burnt gases leaving the combustion chamber enter successively the chambers g, h, i, j, k, l, m, n, o, p, q, r, in which they expand, finally issuing through the exhaust channel 31. From here the exhaust gases pass through the centripetal turbine rotor 22 in which residual energy is recovered. From the centripetal turbine rotor exhaust gases issue through a volute chamber 22' situated near the rotor.

In another modification the toroidal stator 1 has a further convex projection 23, shown in broken lines in figure 4. To conform with this projection the ribs 8 of the rotor 2 are partly cut off. The function of the projection 23 is to modify the pressure curve during the working stroke, particularly with a view to producing a smooth pressure curve. In particular it is desirable to balance the pressures acting on the vanes. The projection 14, which partially or entirely covers the surfaces of some of the vanes, gives rise to unbalanced forces acting on each wheel 4. The second projection 23 reduces this disequilibrium, in addition to influencing the pressure curve during the working stroke.

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Figure 5 is a diagrammatic 3-dimensional view of the rotor 2. Figure 6 is a section taken along the line A—B in figure 4. The path taken by the burnt gases passing from 5 the combustion chamber 17 into the first helicoidal expansion chamber will now be described, with the help of these two figures. From the combustion chamber 17 the burnt gases pass through a port 35 in the bottom of 10 the groove in the rotor, between the first two parts of the rib 8 downstream of the combustion chamber. The port 35 is approximately triangular and has walls curved to allow the burning gases to pass smoothly without 15 abrupt expansion. Abrupt expansion would reduce the efficiency of the engine. In figure 6 two neighbouring vanes of one of the wheels 4 are shown at 36 and 37, the two vanes enclosing between them a rib part 38 which is 20 the first part of the rib 8 situated downstream of the combustion chamber 17. The trailing edge of the rib, with reference to the direction of rotation of the rotor, is indicated at 39. The port 35 has its mouth at the base 25 of the rib part 38. The direction of rotation of the rotor is indicated by the arrow 42. The direction of rotation of the wheel is indicated by the arrow 43. The rib part 38 and the port 35 are shown in the intermediate 30 positions they occupy when burnt gases are flowing into the two helicoidal chambers g and h, on either side of the vane 36. With the rib part 38 in the position shown, the burnt gases enter the helicoidal chambers 44 and 45, the chamber 44 being limited by the surface 39 of the rib, the vane 36 and the part 14 of the stator. On the other hand, when the edge 39 of the rib 38 is in the position 41 represented by the broken line, no gases 40 can enter the helicoidal chamber 44. With rotation of the rotor in the direction of the arrow 42, gases increasingly enter the chamber 44, the flow of gases into the chamber 45 decreasing, until the trailing edge 45 40 of the port 35 reaches the vane 36. In order to prevent an abrupt shut off of the gas flow, which would produce an impact effect, the trailing edge 40 of the port 35 forms an angle with the plane of the wheel. This produces a gradual shutting of the port.

Figure 7 represents diagrammatically the machine of figure 4, to indicate in a general way the different parts of the rotor. The rotor consists of several parts assembled coaxially 55 to facilitate machining operations and the assembling and dismantling of the rotor, and so as to allow the best material of construction to be used for each part. Two parts 46 and 47 serve for volumetric compression. One 60 part 48 is for deflecting the compressed fluid towards the combustion chamber. The three parts 49, 50, 51 are for expansion of the burnt gas. Upstream of the part 46, where the first compression takes place, there is a part 52 which serves for centrifugal precompression.

Downstream of the part 51 in which the last expansion takes place, there is a turbine rotor 53 for recovery of residual energy.

Figure 8 represents diagrammatically a machine according to the invention intended 70 for use as a compressor. Some of its parts correspond to parts in figure 7, but the parts 50, 51, 53 are missing in figure 8, and the part 49 necessarily has a different shape.

In another embodiment of the invention, 75 represented in figures 9, 10 and 11 an engine which is similar to that shown in Fig. 4 and contains a bundle of contiguous tubes through which water circulates, for limiting the temperature in the region of the chambers g and h (figure 4), and two afterburner chambers for improving the thermal efficiency. Figure 9 is a diagrammatical representation of the machine. Figure 11 is an axial section taken along the line A—B in figure 9. Figure 10 is an end view of the machine of figure 9. The stator 1 contains a bundle of contiguous tubes 54 arranged as a layer near the surface of the stator and in contact with the expansion chambers 56, 57, 58, 59. The water circulates in the directions of the arrows, propelled by pumps 55 which are driven by the axles of the wheels. This arrangement has the result that the heat removed from the combustion gases in the region of the first expansion chambers just downstream of the combustion chamber is transferred to the region of the chambers further downstream, reheating the expanding gases. Furthermore, there are two afterburner chambers at the locations 60 and 61, the burnt gases passing into the chambers 59 and 59' through elbow ducts 62 and 63. The two chambers 59 and 59' are for example the chambers n, o, p, q, of the machine of figure 4. Fuel is fed in at the centre of the machine, air being bled off from the region of highest compression and fed into the two combustion chambers 59 and 59'.

Figures 12 to 23 show diagrammatically 110 various other embodiments of the machine according to the invention, each figure being a vertical axial section. In these greatly simplified figures the projections on the stator 1 are represented in section by hatched areas in 115 the drawings.

Figure 12 represents an engine essentially 120 similar to the engine of figure 4, but in which the compressed gases are deflected only partly towards the combustion chamber, that is to say there is a considerable gap 18 between the parts 14 and 32 in figure 4, so that a considerable flow of secondary air passes between these parts.

Figure 13 shows a machine, that is a combination of a compressor and a steam engine 125 64. The steam engine occupies one half of the machine, the other half being the compressor. The hatched areas 65 are projections of the stator, arranged to act as separating 130

walls between the two halves of the machine. The air is sucked in at 66, the compressed air being ejected through 67. The steam passes in at 68 and is exhausted at 69.

Figure 14 represents diagrammatically an internal combustion-compressor combination in which the air is cooled during compression. A deflector 70 deflects the air through an external cooling circuit 71, from which the air returns and flows again through the part of the machine downstream of the deflector 70, as represented by the arrows. Finally the air is deflected by a deflector 73, which acts as a separating wall between the compressor and the engine parts of the machine. Final compression takes place in the region 72. The combustion chamber is shown at 74, for the engine half of the device, the feed of compressed air being indicated at 75.

Figure 15 shows diagrammatically a motor-compressor which has no cooling arrangements. The air is compressed progressively until it is totally deflected by a deflector 70. Part of the air is bled off and fed to the combustion chamber for the motor half of the machine. The bled off air is fed to the combustion chamber as indicated by the arrows f. The burnt mixture enters the central part of the machine and expands to give the working stroke.

The device in figure 16 is a motor-compressor which allows two different fluids to be compressed simultaneously. The part of the device between 80 and 81 is a steam engine, the steam entering at 80 and escaping at 81. A first fluid enters at 76 and, after progressive compression, escapes at 77, where it is totally deflected, as already described above.

A second fluid enters at 78, entering between the stator and the rotor at the other side of the deflector 78. After compression this fluid escapes at 79, being totally deflected by a deflector arranged between this compressor and the steam engine part of the device.

Figure 17 is a refrigerating machine driven by an external motor which is not shown in the drawing. The cold-producing fluid is compressed at 82 and expands at 85. A projection 83 of the stator is interposed between the compression zone and the expansion zone, the projection 83 reducing the cross sections of the chambers formed by the stator and the walls of the helicoidal groove in the rotor, the rotor ribs being partly cut off to give room for the projection 83. A cooler is indicated at 84, for cooling the cold-producing fluid. The cooling circuit of the refrigerant fluid is indicated at 86.

Figure 18 represents the principle of a steam driven motor-pump in which the pump part 87 is completely separated from the motor part 83. The separating wall 89

is in the form of a projecting part of the stator, the projection 89 coming flush with the inner wall of the rotor with practically no clearance. Steam enters the circuit 88 downstream of the projection 89, which retains the steam entirely in the motor circuit 88. The fluid which is being pumped enters the circuit 87 near the periphery of the machine. The pumping chambers retain the same volumes, due to a projection 90 (shown hatched) of the stator, assuming that the fluid is incompressible.

Figures 19 and 20 represent steam engines with and without superheating. In figure 19 the steam flows through the machine in the directions of the arrows. The steam enters chambers of increasing volume between the rotor and the stator, this effect being produced by a projection 91 of the stator, which completely blocks the lefthand part of the machine, as shown in the figure. The projection 91 reduces the volume of the chambers near the steam outlet. In figure 20 a superheater 93 is provided. The steam is deflected entirely into the superheater 93 by a projection 92 of the stator, as indicated by the arrows. After passing through the superheater the steam reenters the circuit downstream of the deflector 92, to pass through the last expansion chambers before escaping.

The device shown in figure 21 is a compressor which gives a high degree of compression. The fluid, flowing in the direction of the arrow, is progressively compressed, the compressive effect being increased by a projection 94, which entirely blocks the righthand side of the machine, the projection 94 also acting as a deflector which compels the highly compressed fluid to leave the machine through the delivery duct indicated at the left in the figure.

Figure 22 is a variant of the device shown in figure 13. In this case there are two deflectors 95 and 96 in place of the single deflector 65 in figure 13. The deflectors 95 and 96 are total deflectors in the form of projections of the stator. Between the two deflectors 95 and 96 there is a chamber 97 which surrounds the central part 100 of the rotor, the chamber 97 being entirely separated from the circuits 98 and 99 of the machine. The chamber 97 is arranged so that it can accommodate a mechanism for driving the rotary valve devices, which are not shown in the figure.

Figure 23 shows a further advantageous version of the invention, this arrangement providing a considerable improvement in regard to the construction of the machine, its method of functioning and its thermal efficiency. In this version of the invention it is the internal solid torus which rotates, the part of the machine containing the hollow torus remaining stationary. Thus the part which remains stationary contains the hollow

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torus containing the helicoidal-spiral grooves in which the vanes of the valve device engage, forming successive compression and expansion chambers. The body of revolution forming the rotor of the machine consists of a rotating shaft, and fixed to the shaft, two bodies of revolution in the form of toruses which are coaxial with the shaft. The stator embraces the two toruses of the rotor and consists of a central part, situated between the two rotor toruses. The central part has surfaces in the form of hollow toruses, each containing a helicoidal-spiral groove whose walls closely embrace, with their edges, the toruses of the rotor. Each rotor torus has a projection, in the region of smaller rotor diameter, in the form of a body of revolution. The projection has the shape of a truncated cone which has a hollow interior. The axis of the truncated cone is coaxial with the axis of the machine. The projection has a surface which is adjacent to a part of complementary shape of the internal surface of the stator, situated between the rotor shaft and the hollow toruses. There is very little clearance between the projecting part of the rotor torus and the complementary surface of the stator.

This arrangement provides considerable advantages. In the first place the machine is more rigid, due to the fact that the parts forming the hollow toruses containing the helicoidal-spiral groove, these parts having relatively thin walls, are now stationary parts and are therefore not subjected to centrifugal forces. If these thin walled parts are subjected to centrifugal forces they tend to deform, reducing the working clearances and giving rise to friction. Furthermore in the present version of the machine the rotating parts are more compact and are situated closer to the axis of rotation of the machine. This alone reduces deformations and stresses.

In the present version of the invention better cooling is provided for the rotor and the stator. These parts are cooled internally. The rotor contains a cooling chamber which cools its entire working surface. Similarly the stator has a cooling chamber which cools the working surface of the hollow torus. The machine is equipped with four valve devices with peripheral vanes. Each valve device is driven in rotation by a drive system which applies drive directly to the vanes. The driving device is in the form of a stationary helicoidal-spiral rib of little height and of truncated conical cross section. The rib projects from the outer surface of a cylindrical sleeve which surrounds the rotor axle in the region between the rotor toruses. The sleeve is fixed to the stator. The helicoidal-spiral driving rib drives the vanes of each valve device directly, this arrangement considerably reducing friction between the vane edges and the walls of the helicoidal-spiral groove

in the hollow torus of the stator. The seal between each compression or expansion chamber and the surface of the rotor torus is improved in that the working edge of each helicoidal-spiral rib of the hollow torus has a working edge of flattened shape. This is the edge which is adjacent to the surface of the rotor torus. The flattened edge extends perpendicular to the rib and its working face, adjacent to the surface of the rotor torus, contains a large number of fine grooves which provide a good seal between neighbouring compression or expansion chambers.

In this version of the invention the machine has a rotor 101, a stator 102 and a double precompressor 103. The rotor 101 consists of a rotating shaft 104 situated on the axis of the machine, two bodies of revolution 105 and 106, both having the same shape and mounted facing each other, symmetrically on each side of the middle part of the stator 102. Each body of revolution 105, 106 consists essentially of a torus split axially into two parts. The torus is fixed to the machine shaft 104 by means of a part 107, 108 which is a body of revolution. The cross section of the part 107, 108 is approximately a truncated cone. Near its peripheral edge each rotor has a part 109, 110, in the form of a body of revolution. The outer surface of the part 109, 110 is adjacent to peripheral edges 111, 112 of the outer parts 113, 114 of the stator 102. Between the parts 109, 110 of the rotor and the peripheral edges 111, 112 of the stator there is a pressure seal, for example a labyrinth seal. The outer walls 113, 114 of the stator 102 are in the form of hollow toruses. Parallel to each of these walls there is a second wall 115, 116, the arrangement forming a chamber 117, 118, through which cooling fluid flows for cooling the stator. Each chamber 117, 118 contains deflector vane 119 forming a multiple rib inside the chamber. Each wall 115, 116 is in the form of a hollow torus. The inner surface of the torus, that is to say the surface facing the rotor torus, has projecting helicoidal-spiral ribs 120, 121. The working edge 122, 123 of each rib is adjacent to the surface of the rotor torus 105, 106, leaving only a very small clearance between the surfaces. The helicoidal-spiral rib 120, 121 is continued inwards until it comes quite close to the machine shaft 104 in the region of a projection 124, 125 of the rotor torus 105, 106, the projection being in the form, in cross section, of a truncated cone, which is hollow inside. In the interior of each rotor torus 105, 106 there is an internal chamber 126 containing radial vanes. The chamber 126 is adjacent to the internal surface of the torus and contains a circulating cooling fluid. The cooling chamber 126 extends around at least half of the periphery of the rotor torus 105, 106. Each cooling chamber 126 is connected

through a channel 127 to a source of cooling fluid which can for example be air. The cooling air leaves the cooling chamber 126 through outlet ports in the walls 109, 110 of the rotor toruses 105, 106, the air escaping to the external atmosphere through a volute which is not shown in the drawing. The source of cooling fluid is preferably, in this version of the invention, a double pre-compressor 103 in the form of a two stage turbine. The precompressor 103 consists of, on the one hand, a 2-part centrifuge 128 and, on the other hand, a second centrifuge 129 downstream of the first. The second centrifuge 129 is situated upstream of an inlet volute which will be described in greater detail further below with the help of figure 24. The air is delivered through this volute to the first compression chamber formed by the helicoidal-spiral rib 120, 121, by the rotor torus 105, 106 and by the vanes 130 of the valve devices. Each valve device has four vanes which rotate in an axial plane of the machine. Such a valve device is shown in greater detail in figure 27. Each rotor torus 105, 106 has two oppositely situated valve devices which are mounted to rotate on shafts between the two half-toruses which together make up each rotor torus,

The air leaves the first centrifuge on the one hand through a volute 132 for the cooling air and, on the other hand, through a diffuser 133 and a volute 134 for the pre-compressed air which is fed to the centrifuge 129, from which the air leaves through a double volute 135, which is shown in greater detail in figure 24. The double volute 135 progressively slows down the current of compressed air leaving the centrifuge 129, so that this air reaches the inlet of the first compression chamber in the helicoidal-spiral groove almost without any change of velocity. In a variant of the invention, in which the fluid leaving the first centrifuge for the purpose of cooling the chambers 117, 118 in the stator is not air but water, the collector volute 132 is replaced by a radiator 132', represented by a broken line in the drawing.

The stator 102 has a central sleeve 136 whose two ends, near where the rotor toruses are fixed to the shaft, have helicoidal-spiral external truncated ribs 137 of little height. These ribs act as guides guiding the edges of the vanes of the valve device. The helicoidal-spiral rib 137 is a truncated part of the helicoidal-spiral rib 120, as shown in greater detail in figure 25. The sleeve 136 also has two bodies of revolution 138, 139 which have shapes complementary to the two parts 124, 125 of the rotor toruses 105, 106, so that there remain very little clearance between these surfaces. The sleeve 136 has a further truncated helicoidal-spiral rib 140 of little height, along which are guided the middle notches in the edges of the valve device vanes (compare figure 25).

Projecting from the bottom of each helicoidal-spiral groove between the ribs 120, 121 there is a middle helicoidal-spiral rib of little height 120' which forms a continuation of the rib 140.

The middle part of the stator 102, near the parts 124, 138 and 125, 139, contains two openings 141, 142 which are connected by channels 143, 144, shown in broken lines, to an outlet channel 145 for the compressed air. The channels 146 and 147 feed cooling air to the cooling chambers 117 and 118. The channels 148 and 149 feed precompressed air from the double volute 135 to the compression chambers of the two parts of the machine (a broken line leaving the outlet 149 indicates the channel which is connected to the inlet of the machine, at the right near the bottom in the drawing). Finally the end of the machine opposite the precompressor is closed by a part 150 of the stator, this part being mounted by means of a bearing on the axle of the machine.

Figure 24 represents diagrammatically the double volute 135 situated at the outlet of the second precompressor centrifuge 129, the figure being a transverse section of the machine at the outlet of the centrifuge 129.

In figure 25 a vane 130, fixed to the hub of a valve device (not shown) by two screws 151, is guided by a notch 152 in its peripheral edge, the notch engaging over the helicoidal-spiral truncated rib 140 of the sleeve 136 fixed to the stator 102. The notch 152 engages precisely with the surface of the rib 140, so that the vane 130 is precisely guided along the rib 140. The figure also shows the other truncated rib 137 of little height, which precisely continues the helicoidal-spiral rib 120. In view of the fact that there is extremely little clearance between the parts 140 and 152, these parts acting as guides for the vane, no friction occurs between the parts 130 and 120/137 between which there is more clearance.

Figure 26 shows two vanes 130 attached by screws 151 to the hub (not shown) of a valve device, the vanes engaging in a helicoidal-spiral grooves, defined for example by ribs 120 or 121. The rib 120 has a flattened end 152 extending perpendicular to the axis of the vane, the face 153 of the end being adjacent to the outer surface of the torus (represented diagrammatically by the line 154). The face 153 has a large number of fine grooves 155 whose function it is to improve the seal between the compression and/or expansion chambers.

Figure 27 is a diagrammatic section through the machine, taken in a plane containing the axis of a valve device 131 which consists of a hub 156 and vanes 130. The hub rotates on a pin 157 which passes through a

central bore in the hub. The vanes 130 are attached by screws 151 to the periphery of the hub. The two half-toruses 158, 159 completely enclose between them the hub. The two half-toruses 158, 159 are joined together for example by bolts 160. The hub 156 rotates between inclined ball or roller bearings 161.

The machine can be in the form of an assembly of parts which can if desired be of different materials of construction, in particular materials having different degrees of heat resistance, different mechanical strengths and different coefficients of friction. In the process of assembling the valve devices, the two-half toruses can first be screwed together with the hub of the valve device between them, the vanes being screwed to the hub subsequently.

The machine functions as follows:

The precompressor 103 constantly feeds air to the cooling circuits 146, 147, 117, 118 and also air to the second precompressor 129, through a diffuser 133. The precompressed air passes through the volutes 148 and 149 into the two helicoidal-spiral grooves limited by the ribs 120, 121, the toruses 105, 106 and the vanes 130 of the valve devices 131. With rotation of the toruses of the rotor, the air in the chambers is progressively compressed between the vanes. The compressed air leaves the chambers through the openings 141 and 142, passing through the channels 143, 144 into a common air outlet channel 145. The cooling air leaves the cooling chambers 117, 118 through channels 143', 144', 145', arranged in much the same way as the channels 143, 144, 145. Moreover cooling air entering channels such as the channel 127 in the toruses 105, 106 escapes through openings such as 109' in the parts 109 and 110 of the toruses, the air finally leaving through a volute, not shown in the drawing, which communicates with the external atmosphere.

Figures 28 to 33 show very diagrammatically various different ways of assembling the machine according to the invention.

In figures 28 and 29, the two parts of the machine are indicated in a general way at a and b. In figure 28, which is the reverse of figure 23, the two parts can take the form of two compressors functioning either in parallel or in series, the air circulating as indicated by the arrows.

Figures 30 and 31 show two ways of assembling the machine according to the invention. The connecting channels between the two symmetrical parts a and b of the machine allow the output of the machine to be increased. Figures 32 and 33, on the other hand, show two arrangements in which the connecting channels between the two parts a and b of the machine allow the pressure to be increased in the air passing through the machine.

In these figures it should be observed that if the machine is a motor, the parts a are the compressor, the parts b representing the part of the machine containing the expansion chambers. This part of the machine can be developed to provide a more complete working stroke during the expansion of the gas.

WHAT I CLAIM IS:—

1. A rotary machine which can be used as a motor, a compressor or a motor-compressor, comprising a first member in the form of a rotor which rotates inside a second member in the form of a stator, the machine being arranged such a way that working fluid is compressed and subsequently expands in a succession of chambers of first decreasing and then increasing volume, limited by the walls of at least one helicoidal-spiral groove in the surface of one of the said members (that is, either the rotor or the stator), by the wall of the other of said members (that is, either the stator or the rotor) and by at least one valve device whose peripheral vanes engage in the groove, the valve device rotating in a longitudinal plane of symmetry of one of the said rotor or stator members, characterised in that one of the said stator or rotor members has at least one projecting part in the form of a body of revolution, the other of said rotor or stator members, the surface of which is provided with the said helicoidal-spiral groove, having at least one wall part obtained by a complete truncature of the ribs of the helicoidal-spiral groove in the region facing the said projecting part and having a shape complementary thereto, there being very little clearance between these parts, which are shaped and arranged in the machine so as to modify the flow of fluid through the machine in such a manner that the fluid is subjected to an additional greater compression.

2. A machine according to claim 1 for use as a motor, characterised in that the machine is equipped with a centripetal turbine for recovering the residual energy, the rotating part of the turbine being situated in the path of the fluid escaping from the last expansion chamber of the rotor through an outlet opening at the periphery of the rotor and of the stator, the outlet of the turbine being near the longitudinal axis of rotation of the machine in a recovery volute.

3. A machine according to one of the claims 1 or 2 characterised in that in its axial end, near the compression chambers, the rotor has a combustion chamber for burning a mixture of compressed fluid and injected fuel, and deflectors for deflecting the fluid into the combustion chamber.

4. A machine according to claim 3, characterised in that the deflectors for deflecting

the fluid towards the combustion chamber consist of, on the one hand, a projection, in the form of a body of revolution, projecting from the inner part of the stator and having a face which comes very close to a part of complementary shape of the wall of the rotor, so that there remains a very small clearance between the two surfaces and, on the other hand, channels which connect the last compression chambers, situated upstream of the projecting part of the stator, and upstream of the adjacent part of the rotor, to the combustion chamber, the arrangement being such that the part of the helicoidal groove in the rotor which is opposite the projection of the internal stator has walls which are partly or entirely cut way in adaptation to the surface of the projection, so as to leave only a very small clearance.

5 5. A machine according to claims 1, 2, 3 and 4 characterised in that the bottom of the helicoidal-spiral grooves contains, downstream of the combustion chamber, at least one triangular aperture connecting the combustion chamber with the first expansion chamber, which is downstream of the combustion chamber.

10 6. A machine according to claims 1, 2, 3 and 4 characterised in that a part of the surface of the inner part of the stator, forming a wall of the expansion chambers, has a projection in the form of a body of revolution, only a very small clearance remaining between the surface of the projection and the walls of the helicoidal-spiral groove in the rotor, which are partly cut away in this region.

15 7. A machine according to one of the claims 1, 2, 3, 4, 5 or 6, characterised in that the machine has two extra combustion chambers connected to the two last expansion chambers and acting as afterburner chambers.

20 8. A machine according to claim 1, characterised in that the rotor, which is a body of revolution, consists of a rotating shaft and, fixed to the shaft, two toruses, also bodies of revolution, each coaxial with the shaft, the stator, which surrounds the rotor, consisting of a central part, situated between the toruses, with surfaces in the form of hollow toruses, each of these surfaces containing a helicoidal-spiral groove the edges of whose walls entirely embrace the toruses of the rotor, the rotor toruses each having, near the region of least diameter, a projection in the form of a hollow truncated cone, also a body of revolution, coaxial with the axis of the machine, the truncated cone being adjacent, with little clearance to a part of complementary shape of the inner surface of the stator between the rotor shaft and the rotor toruses.

25 9. A machine according to claim 8, characterised in that each rotor torus contains, near its external surface, a chamber through which circulates a coolant fluid, the chamber extending over at least half of the periphery of the torus, the chamber being connected through channels to a source of coolant fluid.

30 10. A machine according to claim 9, characterised in that the source of coolant fluid is part of a centrifugal turbine for precompressing the air, part of the precompressed air being fed through the channels near the middle of the rotor, the air leaving the rotor through a volute communicating with the external atmosphere.

35 11. A machine according to claim 8, characterised in that the stator has a cooling system which completely surrounds the compression or expansion chambers, which are limited by the vanes of the valve device, by the non-cut helicoidal-spiral grooves and by the rotor torus, the cooling system consisting of a series of deflector blades forming a multiple helicoidal-spiral rib which forms the wall of a multiple groove in the chamber between the middle part of the stator and the inner surface of the helicoidal-spiral groove which forms the compression or expansion chambers, a coolant fluid flowing through the multiple groove.

40 12. A machine according to one of the claims 8, 9, 10 or 11 characterised in that the machine is equipped with four valve devices disposed symmetrically with respect to the stator and the rotor, each valve device having vanes engaging in the helicoidal-spiral grooves of the stator, the vanes being guided and driven, on the one hand, by these grooves, whose walls are partly cut off only near the axis of the machine, reducing the wall height and, on the other hand, by a low helicoidal-spiral rib projecting from the bottom of each groove.

45 13. A machine according to one of the claims 8, 9, 10, 11 or 12, wherein each valve device consists of a hub which has a peripheral groove in which are mounted vanes, each vane secured by two transverse screws, the hub of the valve device rotating in the torus on inclined bearings disposed symmetrically with respect to the plane of the vanes, and the said machine being equipped with a driving arrangement for driving the valve devices, the driving arrangement consisting of a sleeve fixed to the stator and situated between the parts of the toruses closest to the rotor shaft, the inner end surfaces of the sleeve forming bearings which bear on the surface of the shaft, the outer end surfaces of the sleeve, having, on the one hand, two truncated helicoidal-spiral ribs of little height, for guiding the vanes of the valve device and, on the other hand, a body of revolution whose shape corresponds to the body of rotation projecting from each rotor torus, one of the truncated helicoidal-spiral ribs having the shape of the truncated helicoidal-spiral rib of little height projecting

50 55 60 65

from the middle of the bottom of the non-truncated helicoidal-spiral grooves forming the compression and expansion chambers, characterised in that the middle part of the peripheral edge of each vane has a notch whose shape is exactly complementary to the shape of the truncated helicoidal-spiral rib of little height which guides the vane.

14. A machine according to one of the claims 8, 9, 10, 11 or 12, characterised in that the non-truncated ribs forming the walls of the helicoidal-spiral grooves forming the compression and expansion chambers have expanded, flattened edges, each edge having a face, adjacent to the surfaces of the rotor torus, containing a large number of fine grooves for making a better seal between adjacent compression or expansion chambers.

15. A rotary machine substantially as hereinbefore described with reference to any of Figures 4 to 33 of the accompanying drawings.

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FIG.2

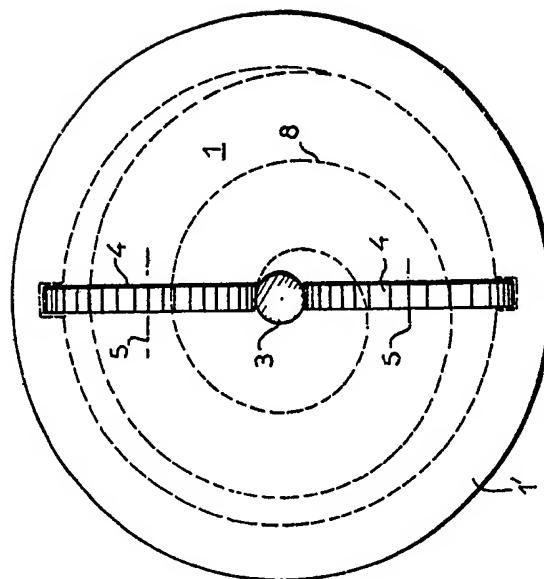
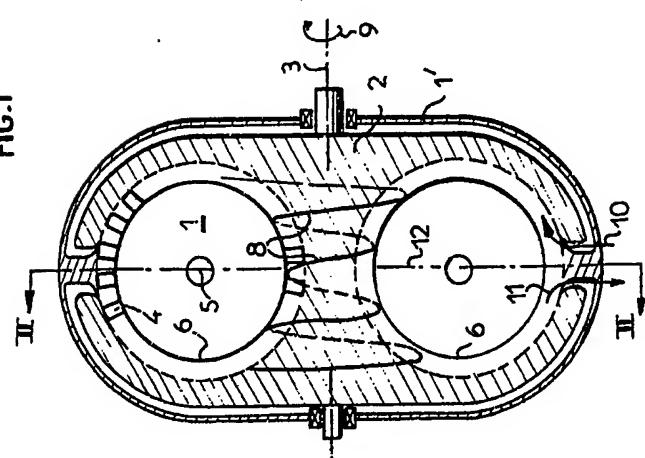


FIG.1

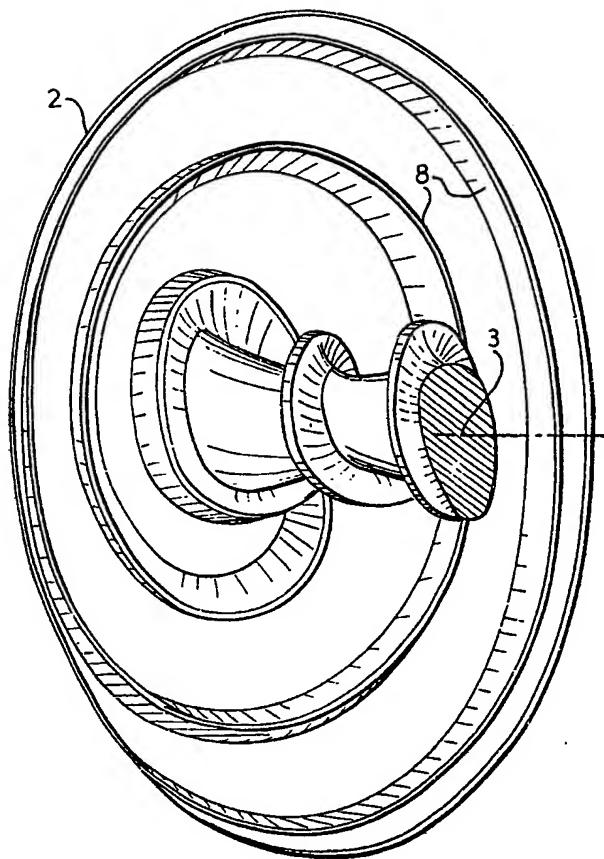


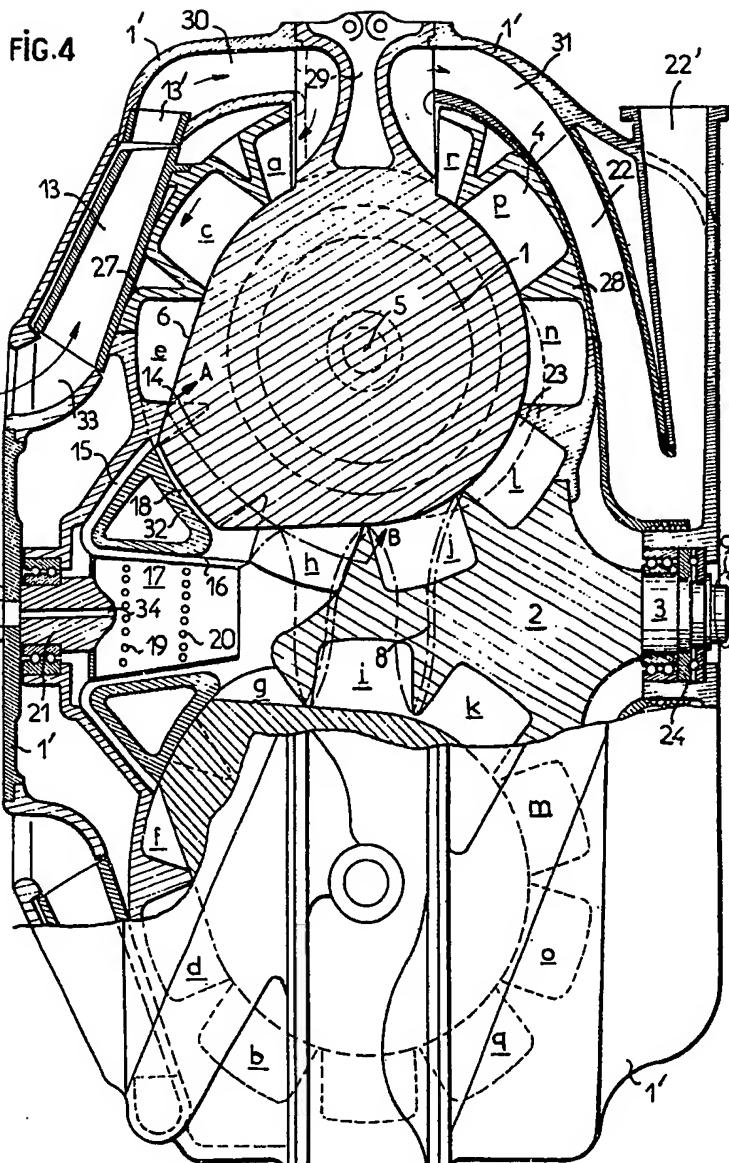
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Sheet 2

FIG.3





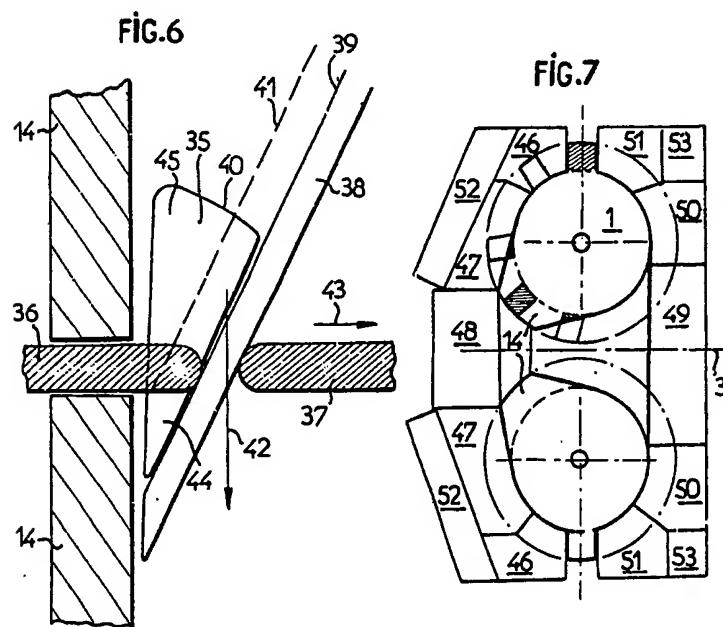
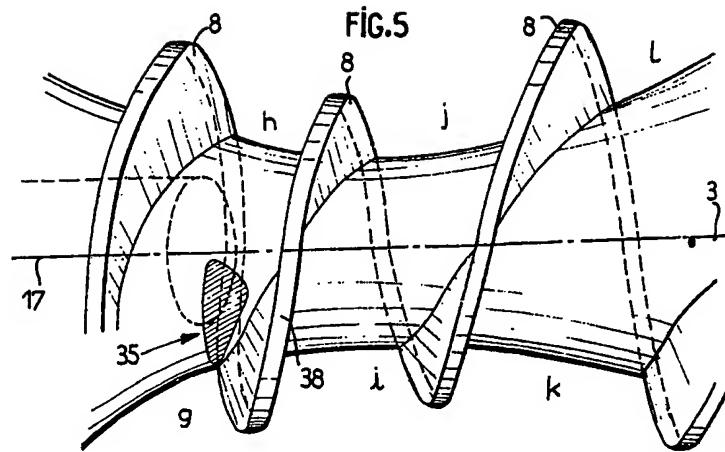


FIG.8

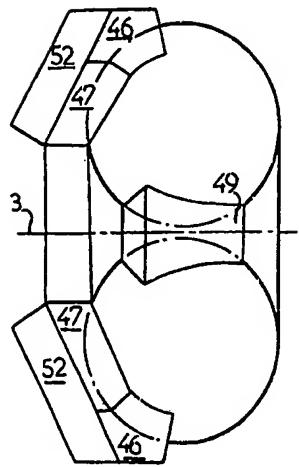


FIG.9

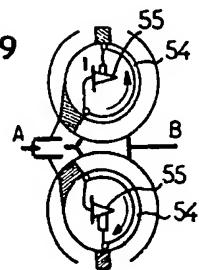


FIG.10

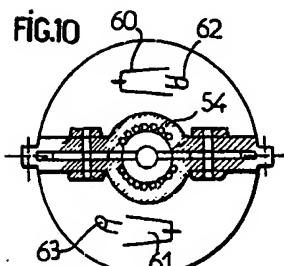


FIG.11

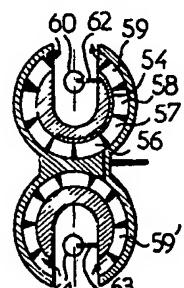


FIG.12

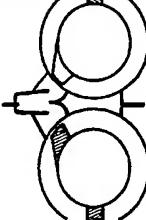


FIG.13

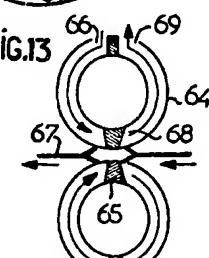


FIG.14

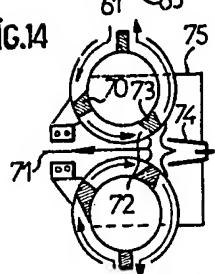
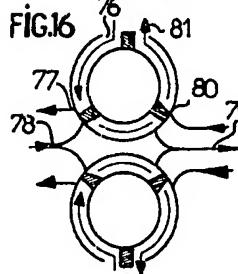
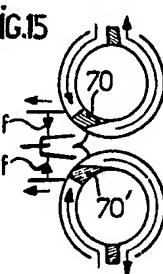
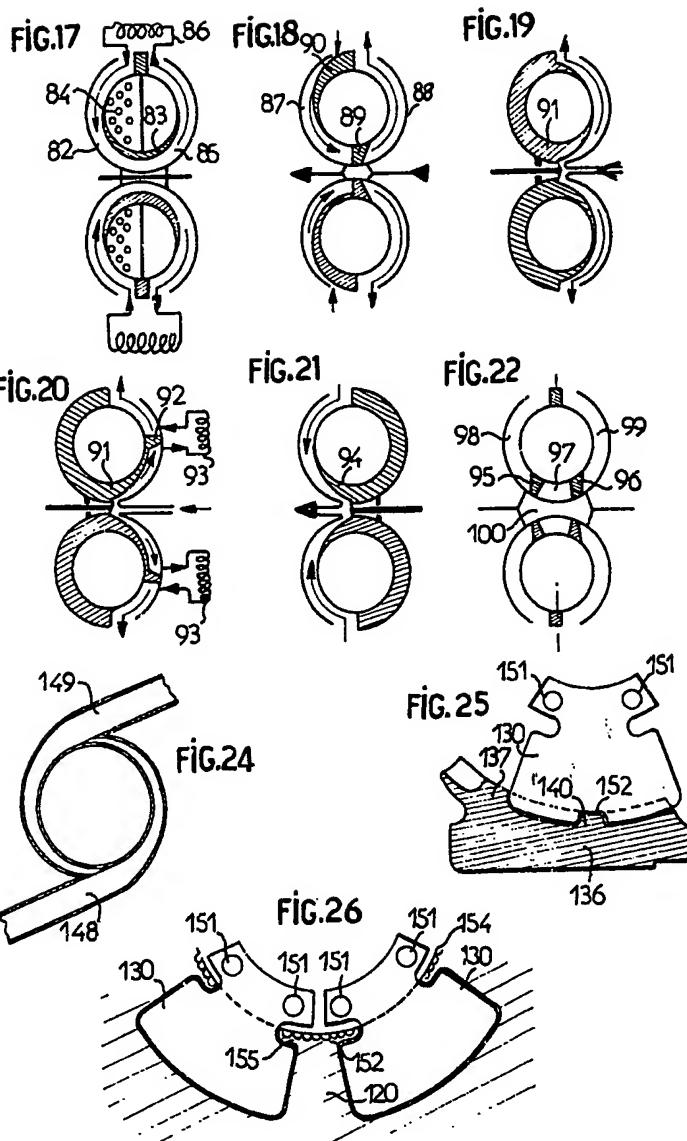


FIG.15





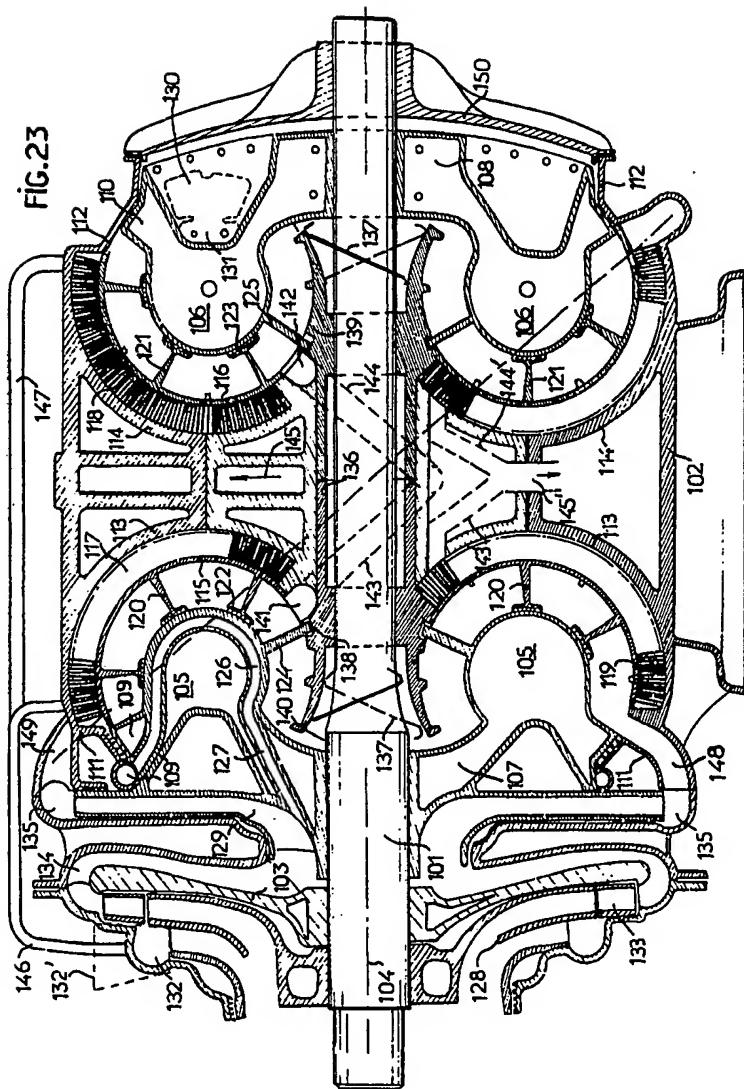
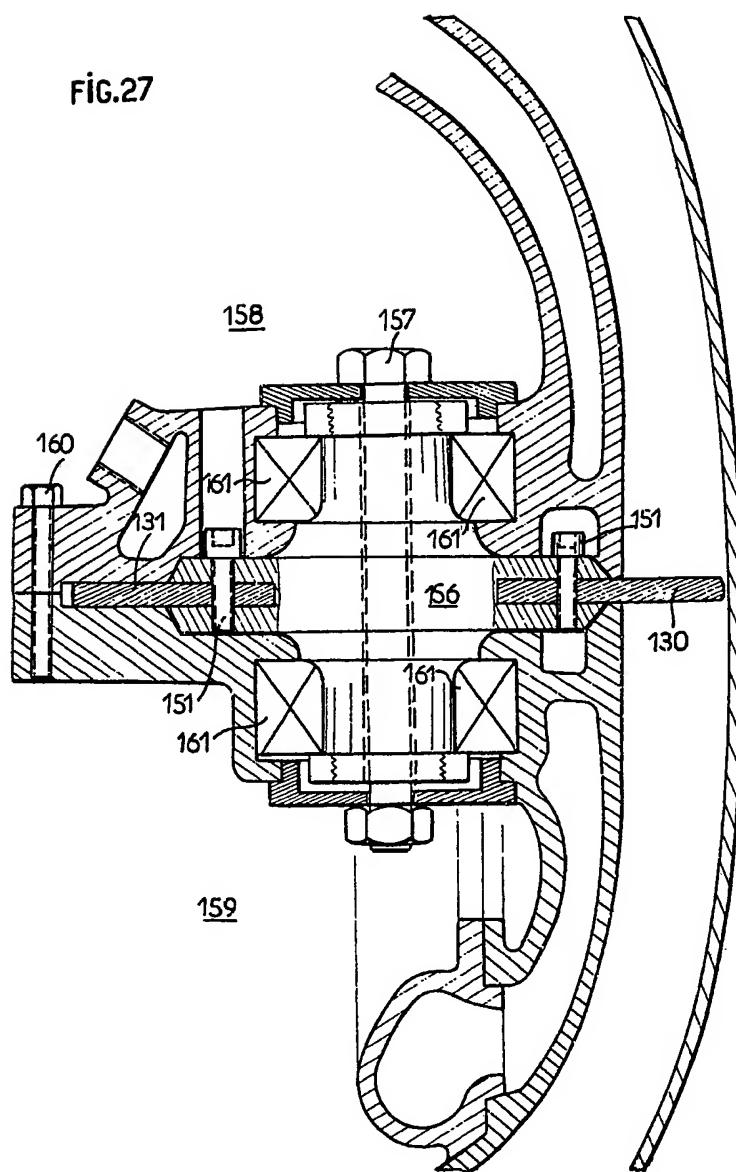


FIG.27



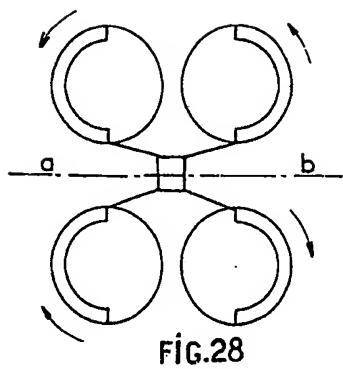


FIG.28

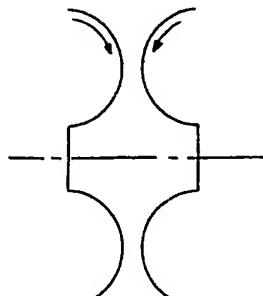


FIG.29

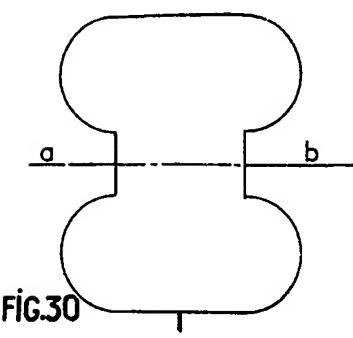


FIG.30

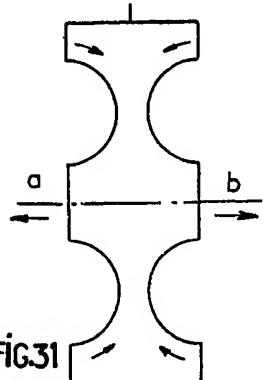


FIG.31

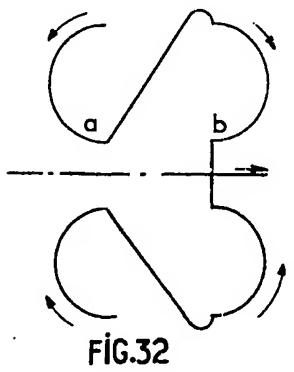


FIG.32

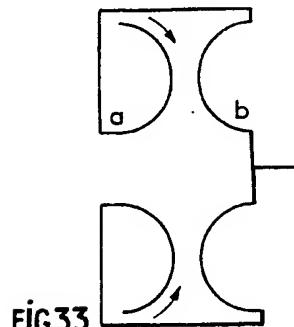


FIG.33

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